Modeling Bioretention Cells Using STELLA®

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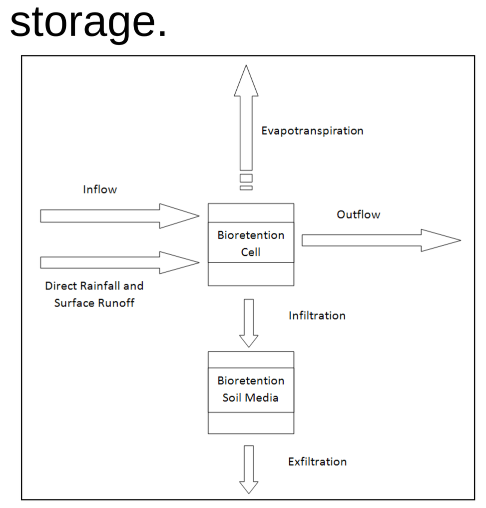
ABSTRACT

The Sand River, located near Aiken, SC (*33.560°N, -81.719°W)* is an intermittent stream that has experienced severe bank and channel erosion as a result of large stormwater flows being discharged from the downtown area of the city. Parkways within the downtown area were retrofitted with green infrastructure practices in April 2011 as part of a project to reduce the volume and peak flow of stormwater being discharged from the Sand River headwaters watershed. These green infrastructure practices included the installation of bioretention cells and porous asphalts. One objective of this study includes modeling the water budget and hydraulic performance within individual cells using the STELLA® modeling software.

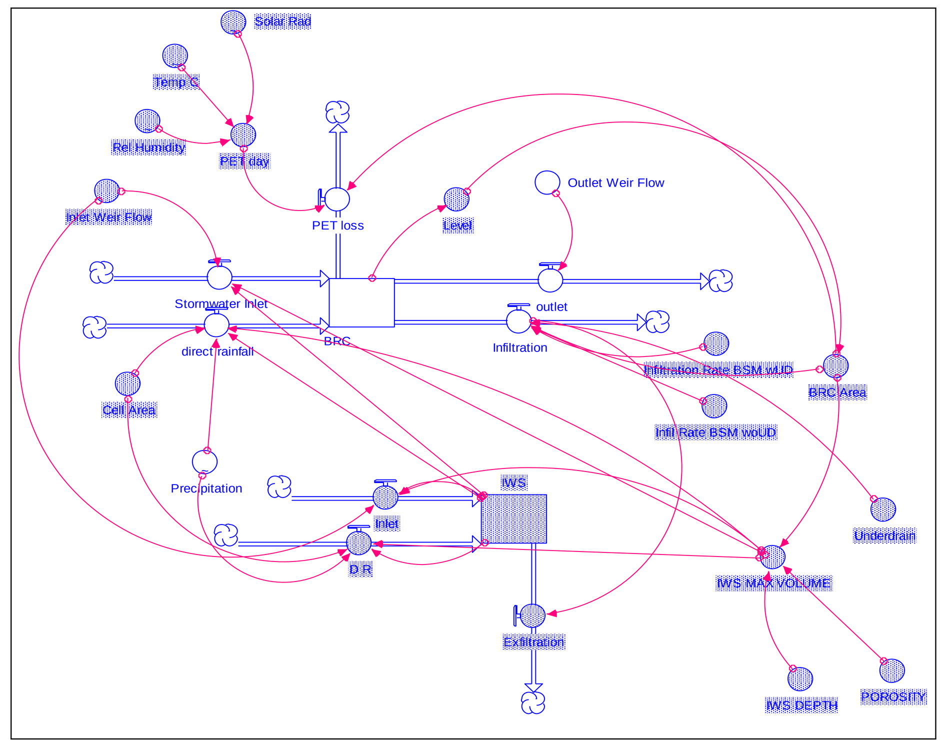
MATERIALS AND METHODS

The bioretention cells were modeled in STELLA® (ISEE Systems, Inc., 2007). This software program allows the user to create a water budget, control the physical parameters of the cell, and produce outputs that may be used to analyze bioretention cell performance and function. The water budget for a bioretention is no different from a general water budget for any retention area. There are inputs (precipitation, surface runoff, and inlet flow), outputs (evapotranspiration, exfiltration, and outlet flow), and storage.



Output Parameter	Symbol	Units	Data Source
Potential Evapotranspiration	PET	mm/day	Calculated from meteorological data
Storage	S	ft^3	Calculated from BRC level data
Level	L	ft	Measured

Input Parameter	Symbol	Units	Data Source
Precipitation	P	in/hr	Measured
Inlet Flow	Q_{in}	ft^3/hr	Calculated from inlet level data
Outlet Flow	Q_{out}	ft^3/hr	Calculated from outlet level data
Infiltration Rate	i	in/hr	Calculated from BRC level data
Relative Humidity	RH	%	Measured
Temperature	T	°C	Measured
Solar Radiation	SR	cal/c m^2	Measured
Cell Area	A	ft^2	Measured
BSM Depth	d	ft	Measured
Porosity	n	-	Measured



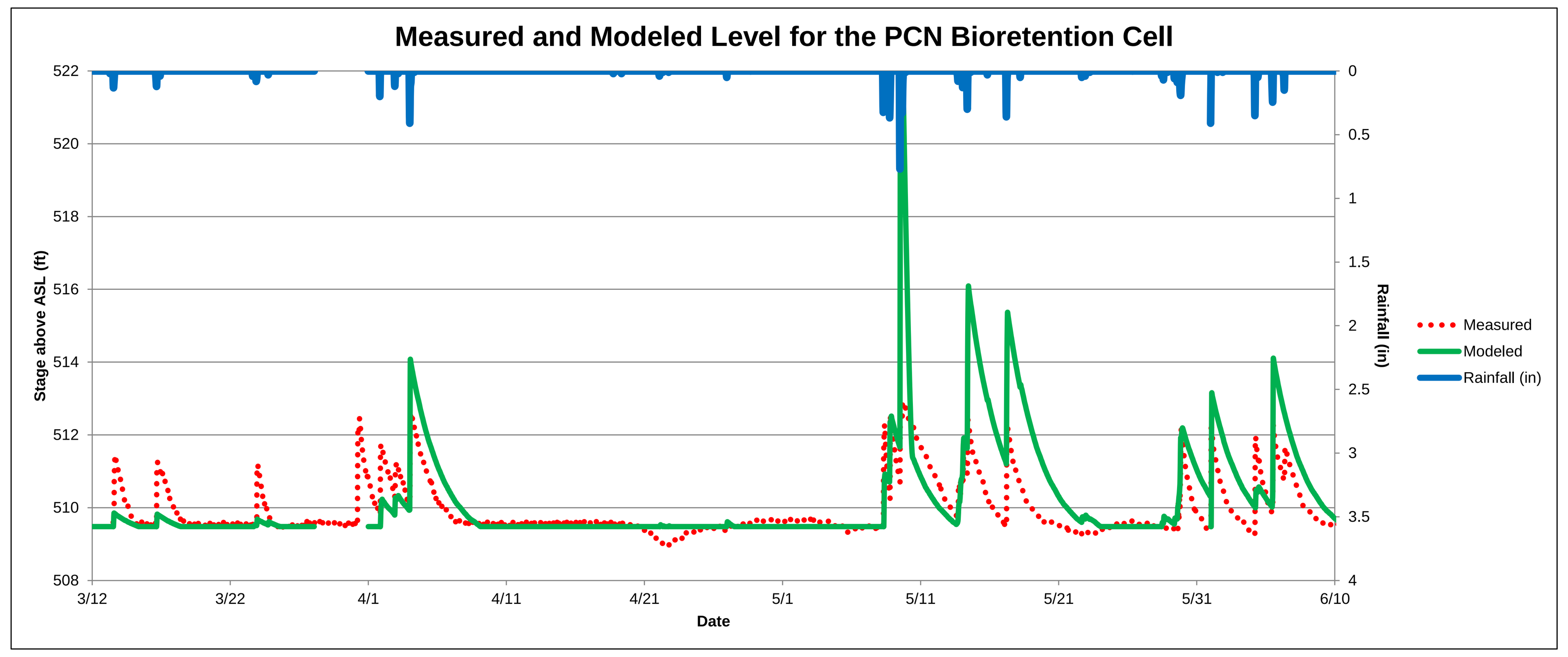
RESULTS

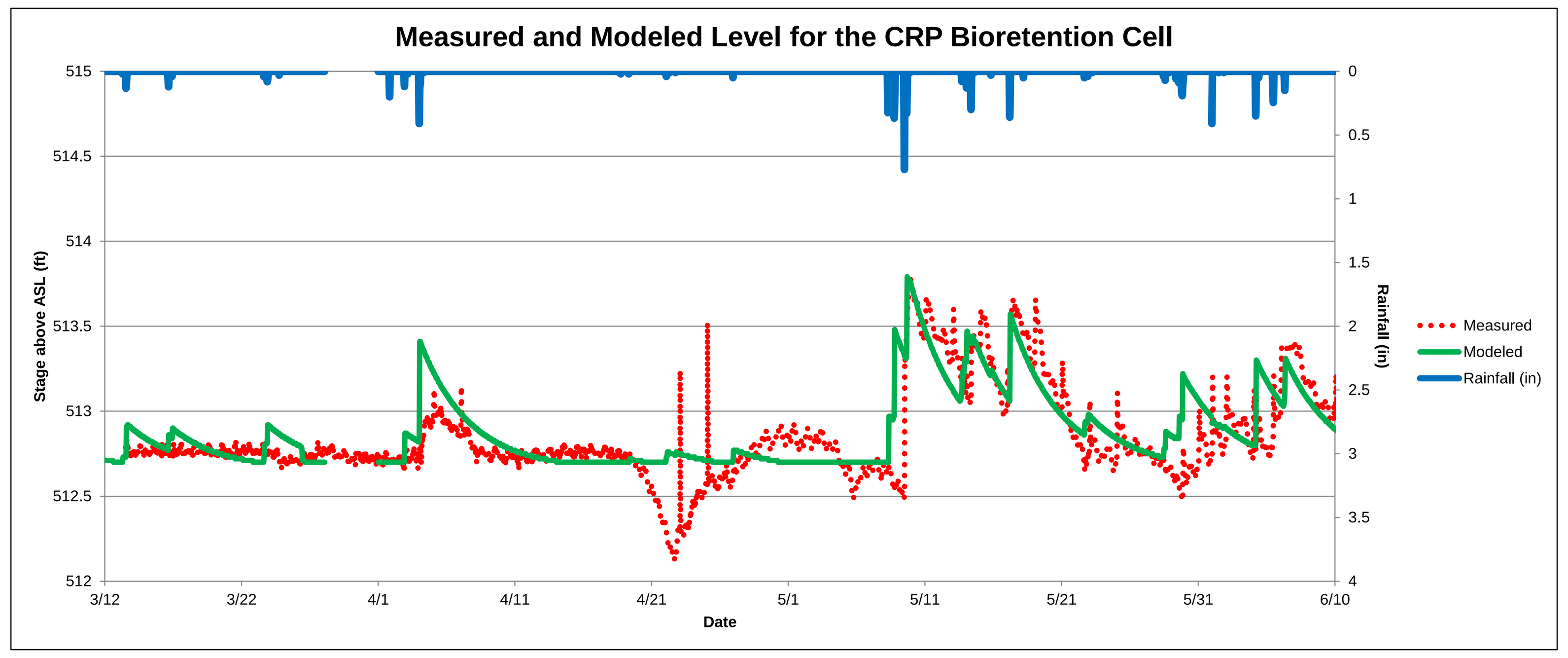
A STELLA® model was constructed and used as a tool to characterize the PCN bioretention cell. The model was built to represent the water budget for the PCN bioretention cell. But, by changing the physical parameters of the cell and using the appropriate input data given in Table 4-3, the model could be used to design and evaluate any bioretention cell. Using data from March – June 2012, the level of captured stormwater in the PCN bioretention cell was modeled. During the modeled period there were 15 storm events of varying duration and intensity. Nash-Sutcliffe coefficients were calculated from the measured and modeled data from each cell to determine the effectiveness of the model. The average and median rainfall for a storm during the modeled time period was 0.71 in. and 0.53 in., respectively. An analysis of the Nash-Sutcliffe coefficients suggests that the model is more effective at predicting the level in the CRP bioretention cell than using only the mean of the measured data, but not as effective at predicting the level in the PCN bioretention cell.

Nash – Sutcliffe Coefficients

	PCN	CRP
R^2_{NS}	-0.70	0.68

This disparity could be due to several reasons including the time step of the model and the input data used to model the PCN cell. The model tended to under-predict storms with rainfall less than 0.25 in. Since the model had a time step of one hour, it is possible that small storms with short durations could be missed. Level data would be more sensitive because the sampling frequency was 10 minutes. Due to the larger time step used in the model and the relatively high infiltration rates of the bioretention soil media and the native subsoil, the smaller storms may have occurred and infiltrated within the one hour period. Using a smaller time step within the model may correct the problem for smaller storms, but it will cause the modeled time span to be much shorter due to the internal restrictions present in the program. Also, using a smaller time step may require more modification of the input data to ensure proper functioning within the program. Larger storms tended to result in the model over-predicting the level in the cell. The likely explanation for storage over-prediction is the method by which the inflow hydrograph for the PCN bioretention cell was analyzed. With backflow being a significant problem with the PCN bioretention cell, each inflow hydrograph was compared to the level data and modified accordingly to represent the actual inflow based on the height of the inlet weir. However, the sampling interval for the level logger was 10 minutes and the sampling interval for the inflow measurements was 5 minutes. As a result, some of the inflow hydrographs may not have been cut off prior to the backflow occurring. This backflow timing issue and subsequent correction error would be most evident during a high intensity, short duration storm like the event that occurred on 5/9/2012. The inflow volume in the model for this storm forces it to grossly over-predict the actual level in the bioretention cell.





CONCLUSIONS

STELLA® models used to evaluate the CRP bioretention cell were effective at predicting measured level. However, modeled data for the PCN bioretention cell were inadequate at predicting the measured level, likely because of the integrity of the input data being compromised by backflow. Quantifying the inflow for the PCN bioretention cell was difficult due to backflow problems frequently occurring and causing an over-calculation of inflow. Due to this difficulty in verifying the actual inflow and the relatively short period of time period of the level data collection, the model was not successfully validated. Further modeling and data collection should be done on the PCN and CRP bioretention cells in order to validate the model as it is currently designed, configured, and parameterized.

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